

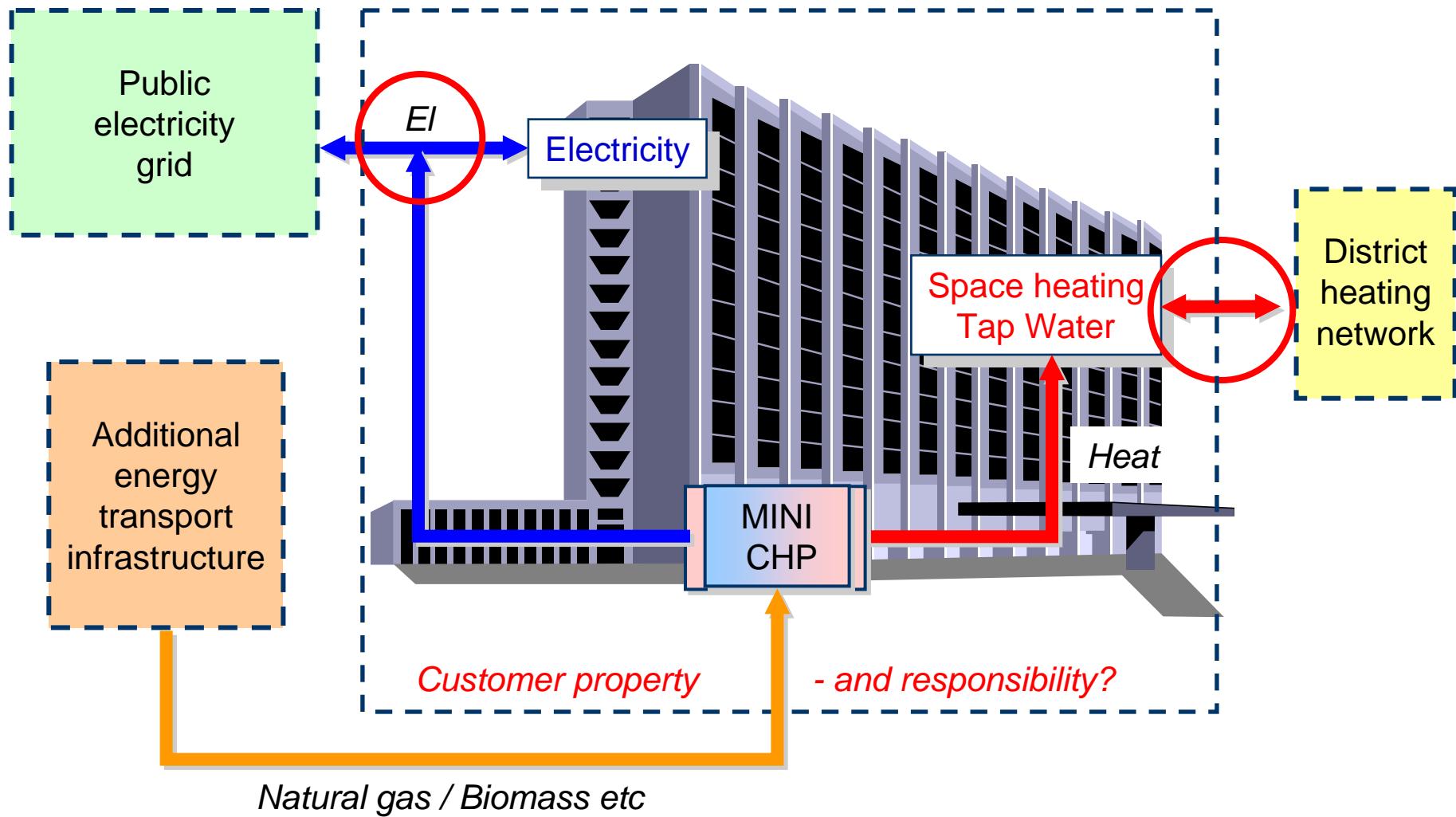
New Tool for Optimisation of Integrated Energy Service Systems

Dr. Bjorn H. Bakken
bjorn.h.bakken@sintef.no

SINTEF Energy Research
N-7465 Trondheim
Norway
www.energy.sintef.no



Integrated Energy Service Systems



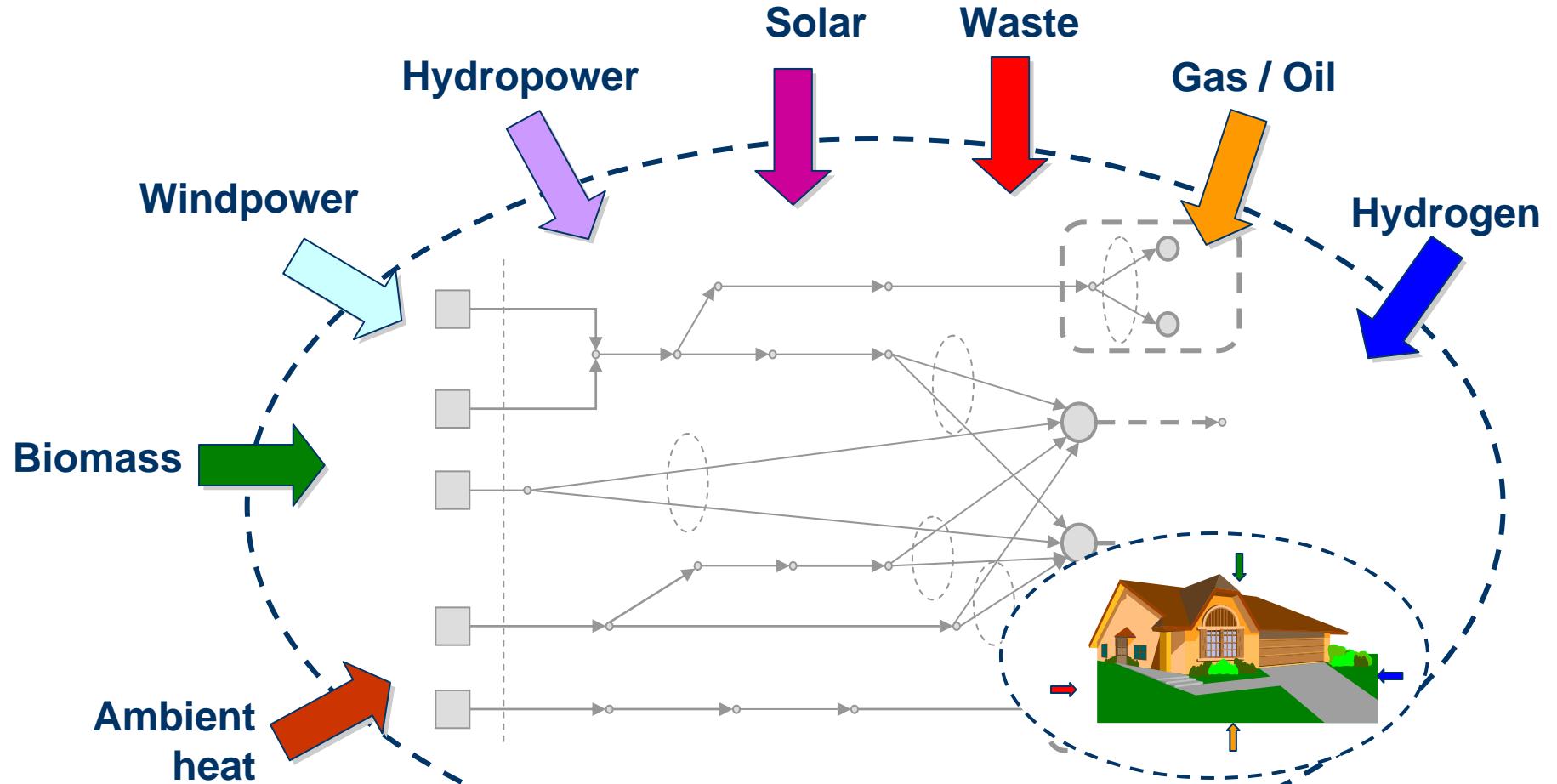
New Tool for Optimisation of Integrated Energy Service Systems

Motivation

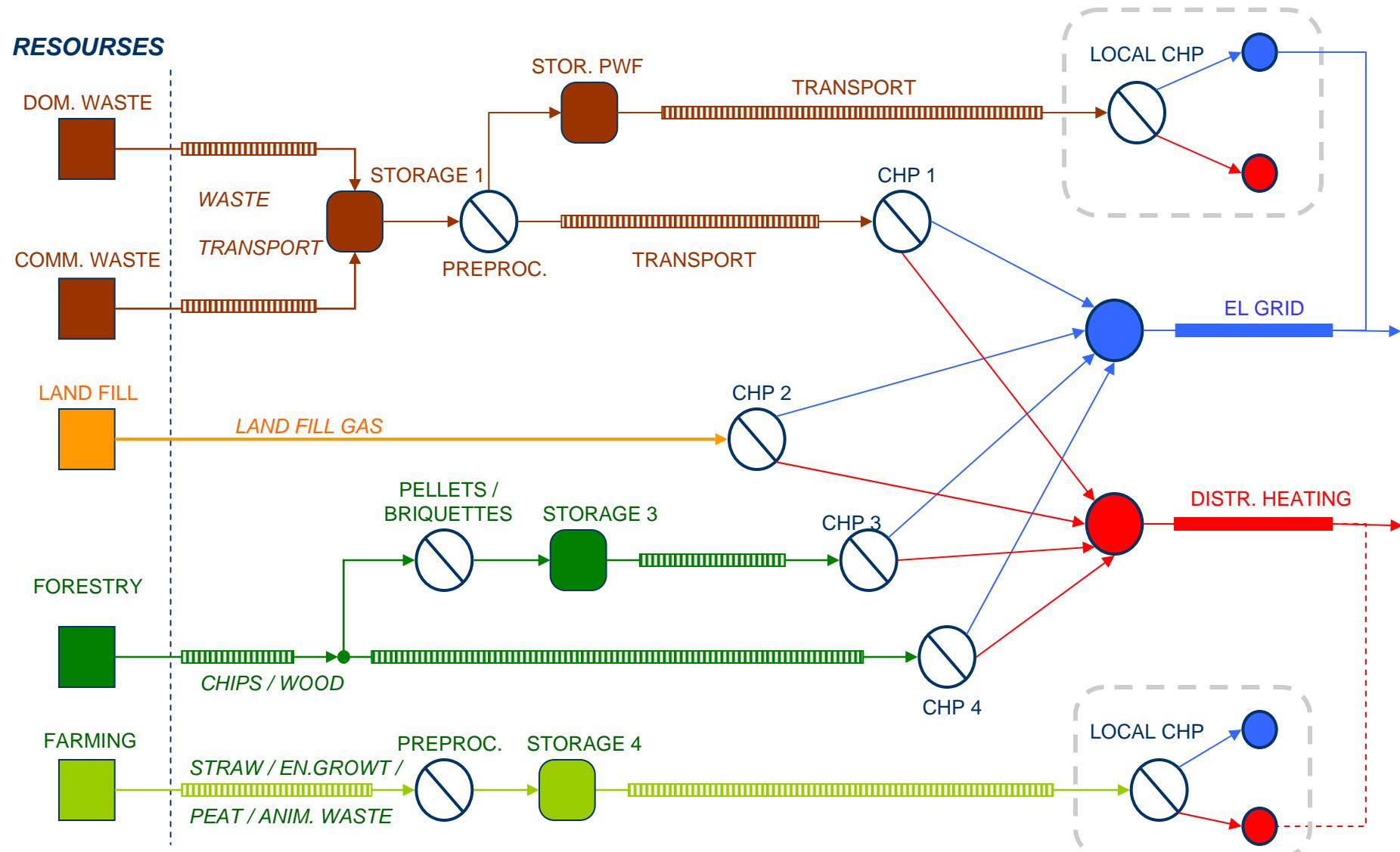


- New technologies for distributed energy systems are emerging
 - better possibilities to design sustainable energy systems for the future
 - more complex energy systems to design, operate and maintain
- From vertical integration to horizontal: *Multi-utilities*
- An overall system perspective is necessary for planning and operation
- Multiple infrastructures and geographic distance must be considered
- More flexible and comprehensive planning tools are needed
- New tool under development at SINTEF with detailed technology models combined in a generic linear network

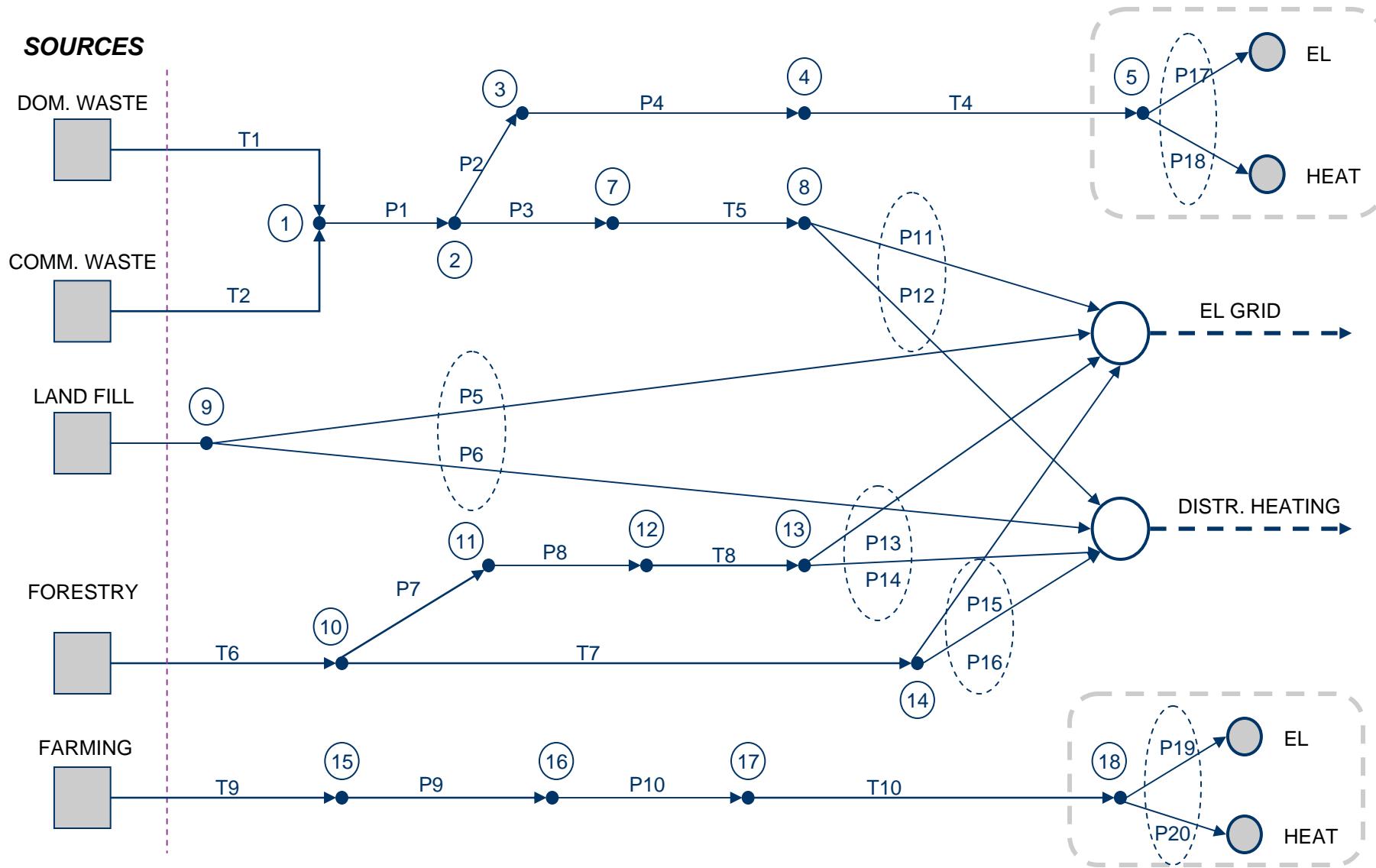
Optimisation of Integrated Energy Service Systems



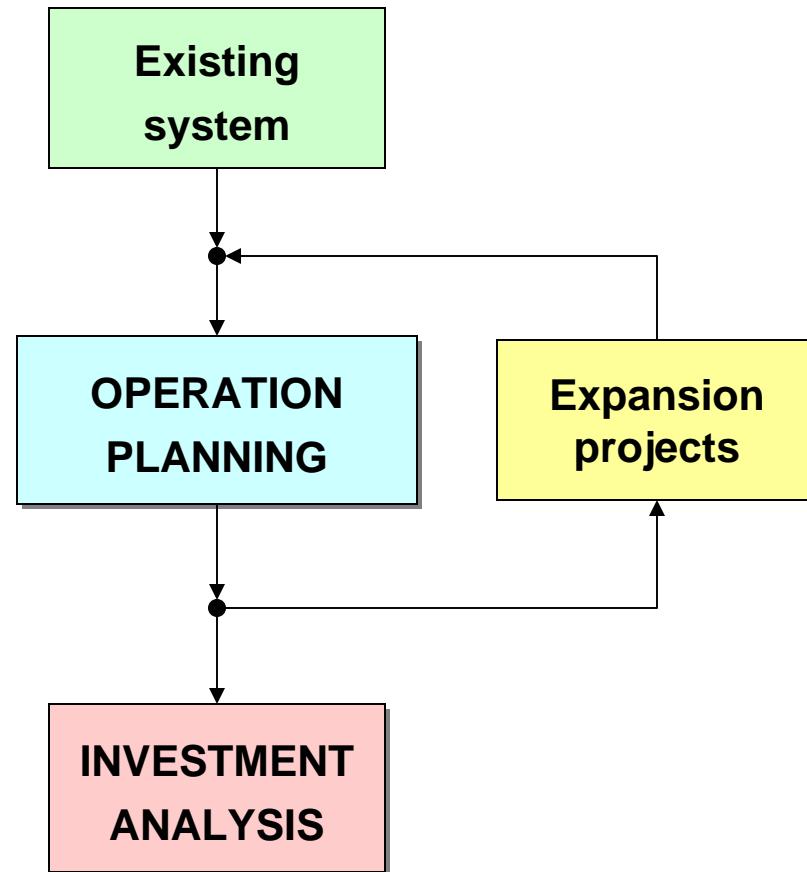
Distributed energy from biomass and waste



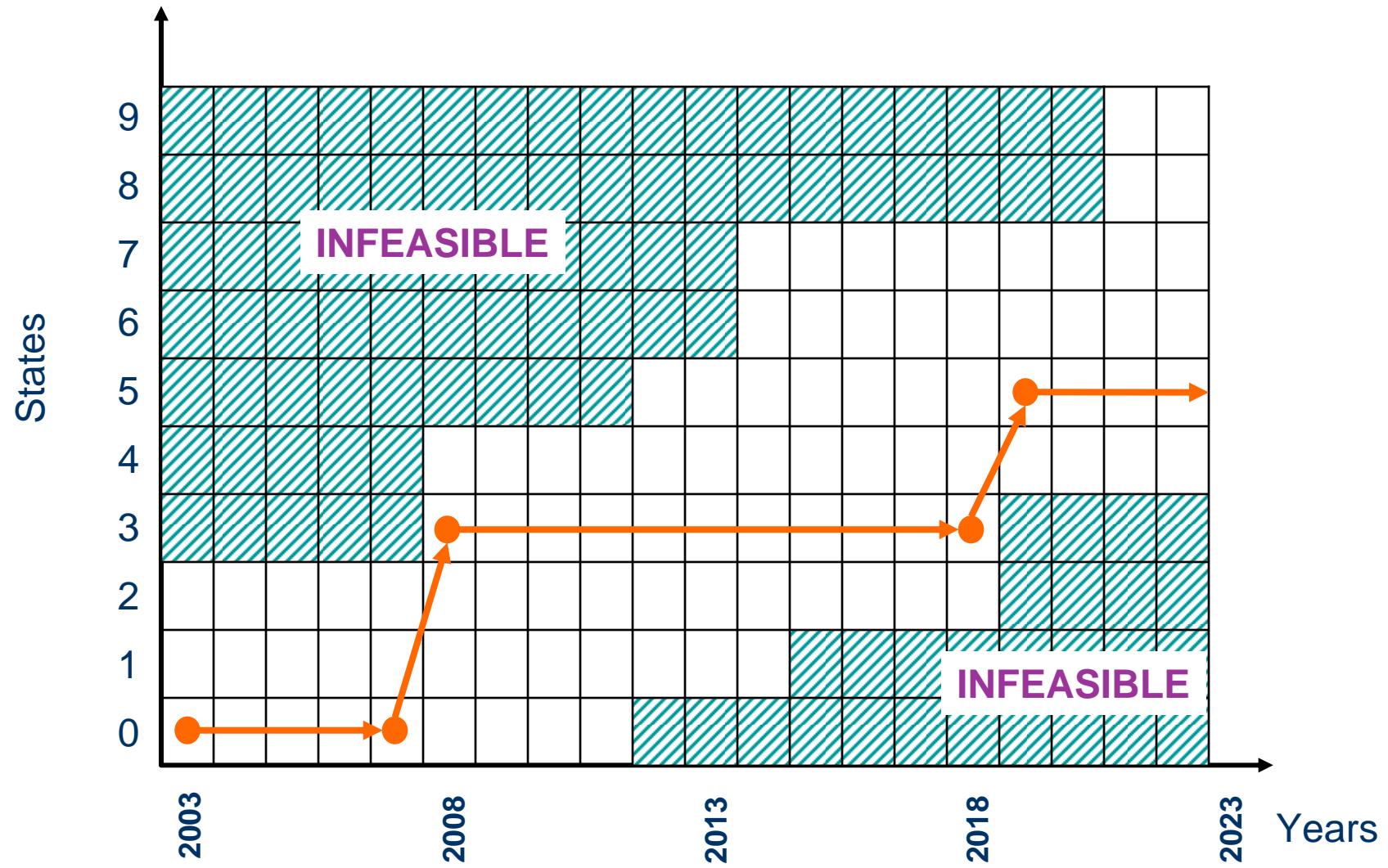
Distributed energy from biomass and waste



Principle of operation and expansion planning



Expansion planning



New Tool for Optimisation of Integrated Energy Service Systems

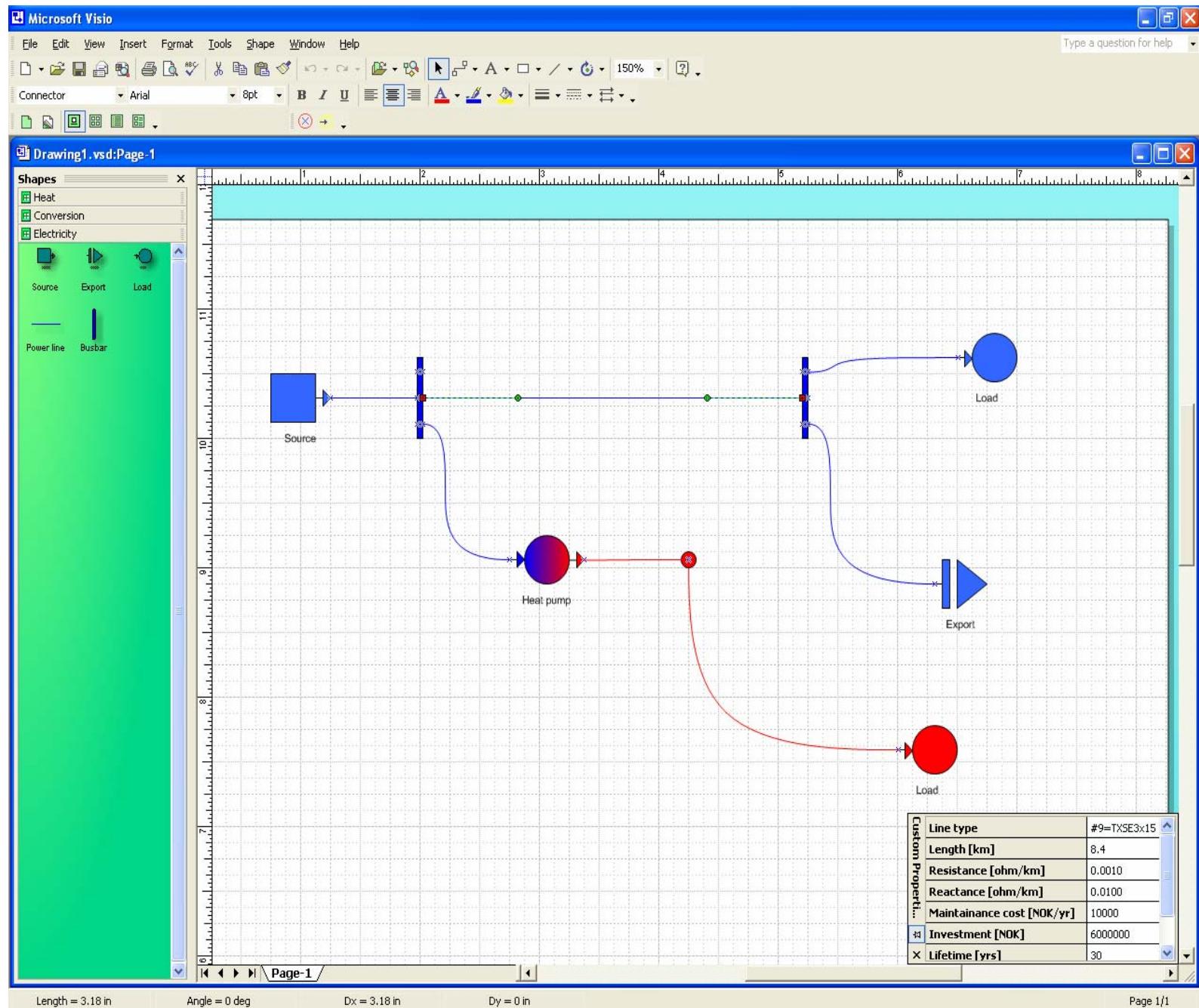
Current modules

- Electricity networks (DC power flow)
- District Heating networks
- Gas pipeline model with compressor
- Discrete transport models (LNG ship and biomass by car)
- 3.5 MW gas fired CHP engine model
- 5 MW gas fired CHP turbine model
- 5 MW gas fired boiler
- Waste fuelled CHP
- 400 MW CCGT model w/ CO_2 sequestration
- LNG factory and reformer
- End user models by function (work, lighting, heating ...)
- Emissions included in object function
- Investment analysis / expansion planning
- Prototype graphical user interface

New Tool for Optimisation of Integrated Energy Service Systems

Mathematical tools

- Linear Programming with MIP extension
- AMPL as matrix generator, CPLEX for solver(s)
 - + Mathematical equations rather than program code
 - + Easy to modify and expand during testing and development
 - + Easy to use in iterations
 - Difficult to implement GUI
 - Possible limitations in tool difficult to bypass
 - Difficult to combine several solvers in AMPL
 - Expensive!
- Graphical user interface in MS Visio
- MS Access database
- Final implementation environment not decided



New Tool for Optimisation of Integrated Energy Service Systems

Case Studies

Melhus:

- ✓ 2002: Waste fuelled CHP with district heating (DH) network modelled
- ✓ 2003: Municipal energy survey
- ✓ 2004: Energy supply infrastructures for biomass

Bergen:

- ✓ 2003: Gas fired CHP with DH network vs. electricity expansion

Trondheim:

- ✓ 2003: Operation of large multi-fuel DH network

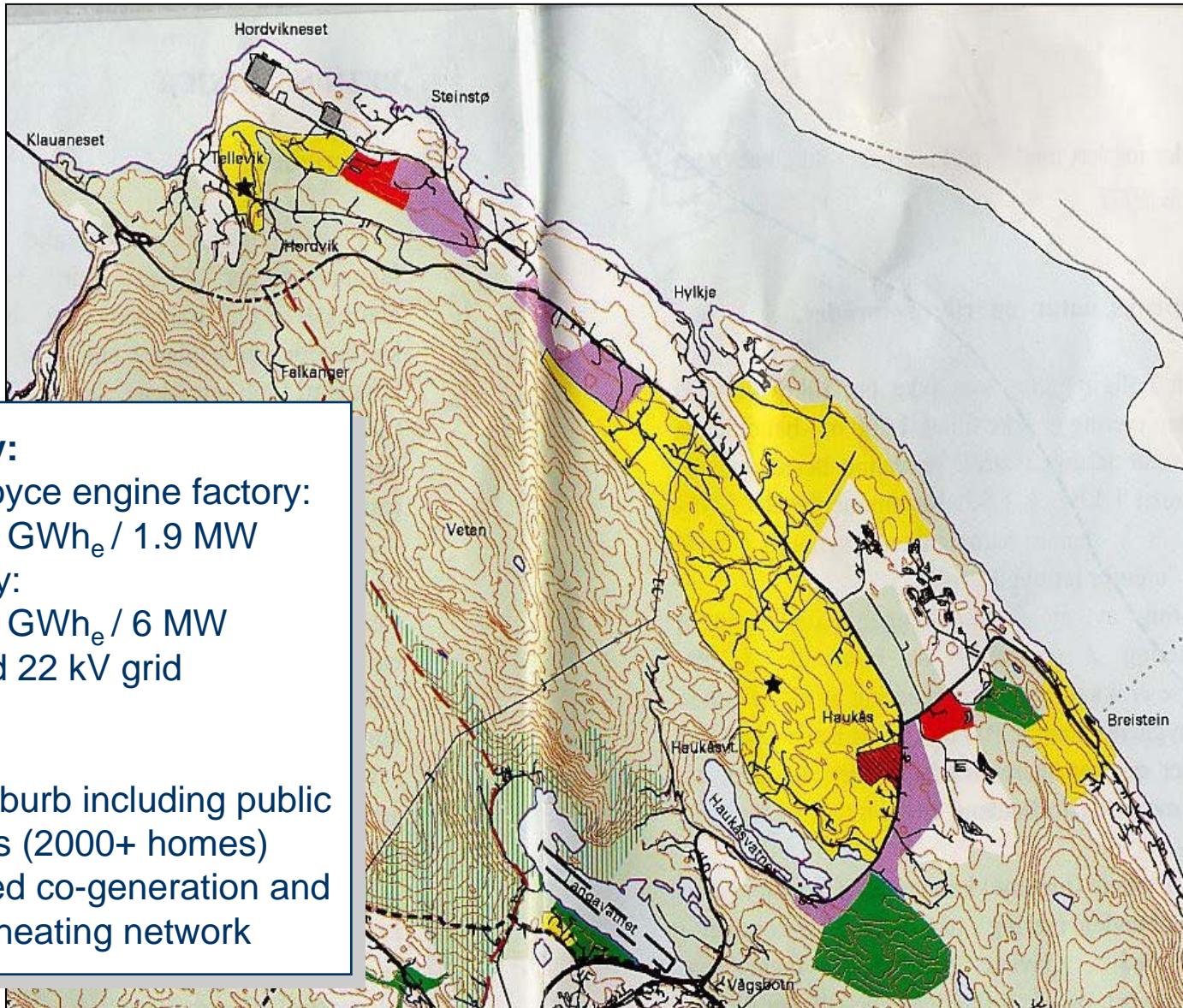
Bulk gas transport:

- ✓ 2003/04: Gas pipelines, LNG ships or HVDC transmission for bulk energy transport

Hydrogen:

- ✓ New case 2004/05 in cooperation with SINTEF Materials Technology?

Case: Hylkje suburb, Bergen



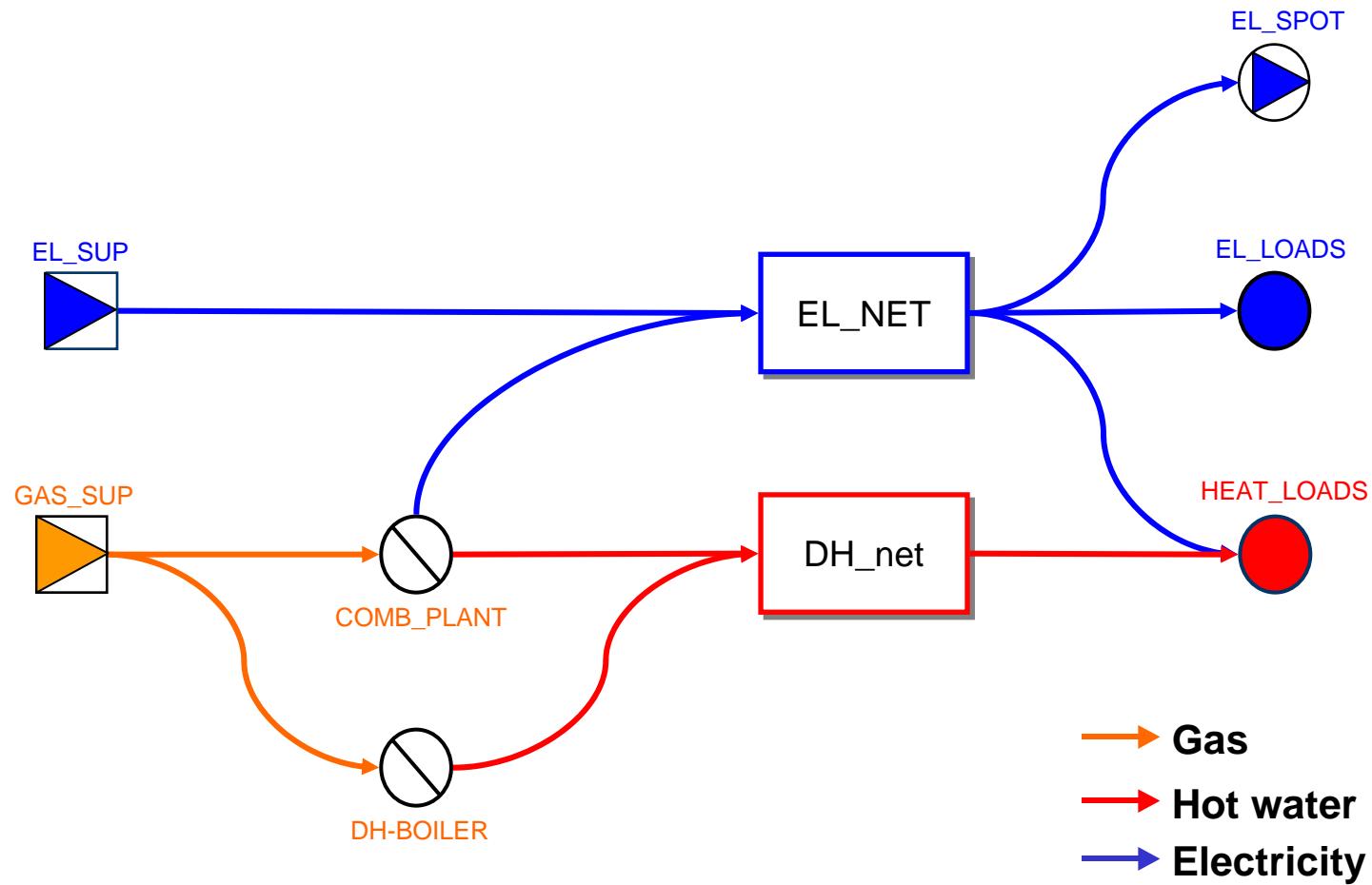
Case: Hylkje suburb

Alternative projects

1. Double electricity supply: New 132 kV line/cable from south
(Base case)
 2. 3.6 MW gas engine at Rolls Royce site with local DH grid
 3. 3.6 MW gas engine at Hylkje supply station with local DH grid
 4. 5.0 MW gas engine at Hylkje supply station with local DH grid
-
- Electricity: 24 hourly spot prices, average for each load segment
(Ref. 2001)
 - Gas: 0.14 USD/Sm² delivered on-site
 - Sensitivity: Electricity price +15%
Gas price +50%

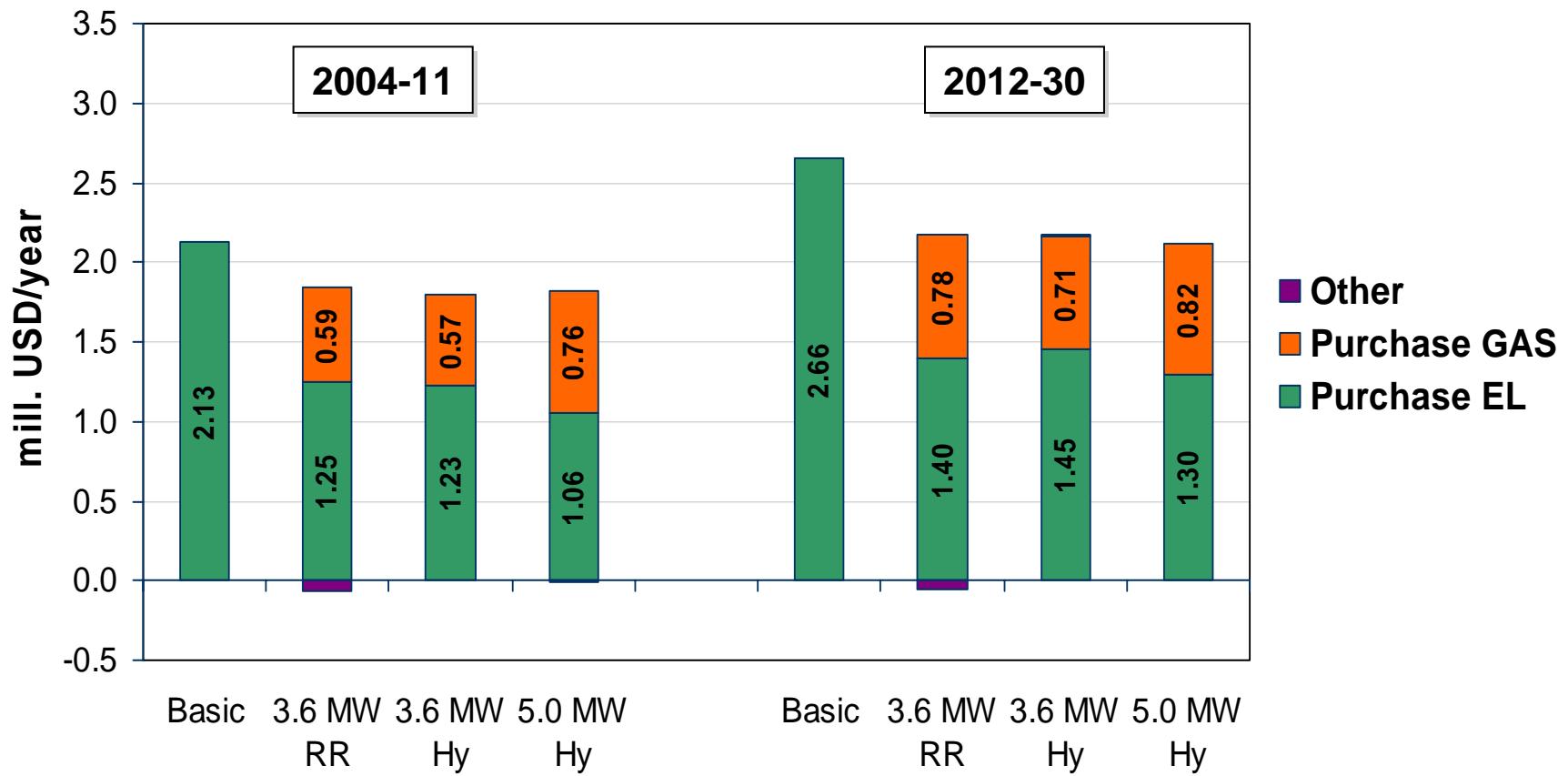
Case: Hylkje suburb

System models



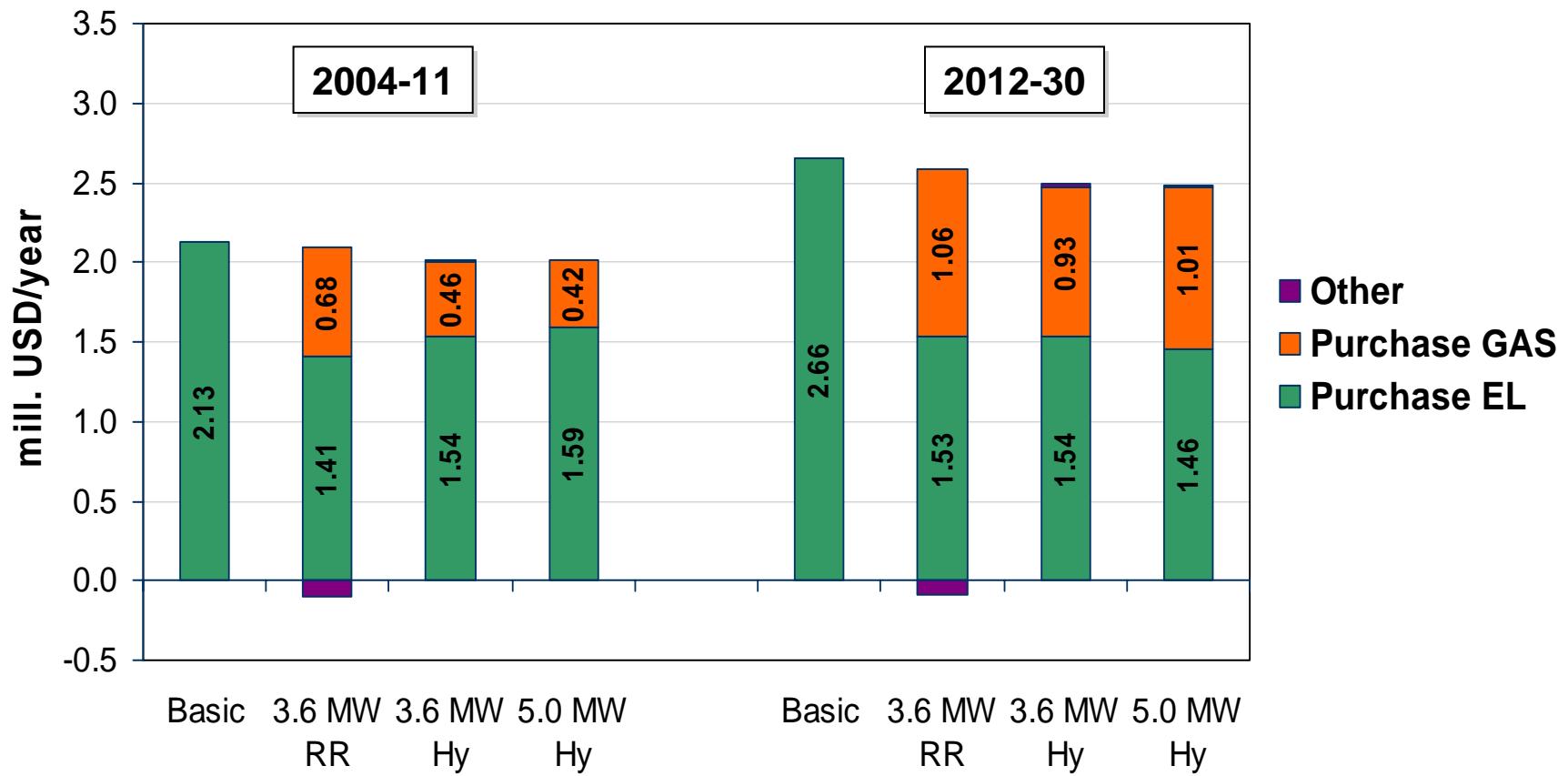
Annual operating costs

Basic assumptions



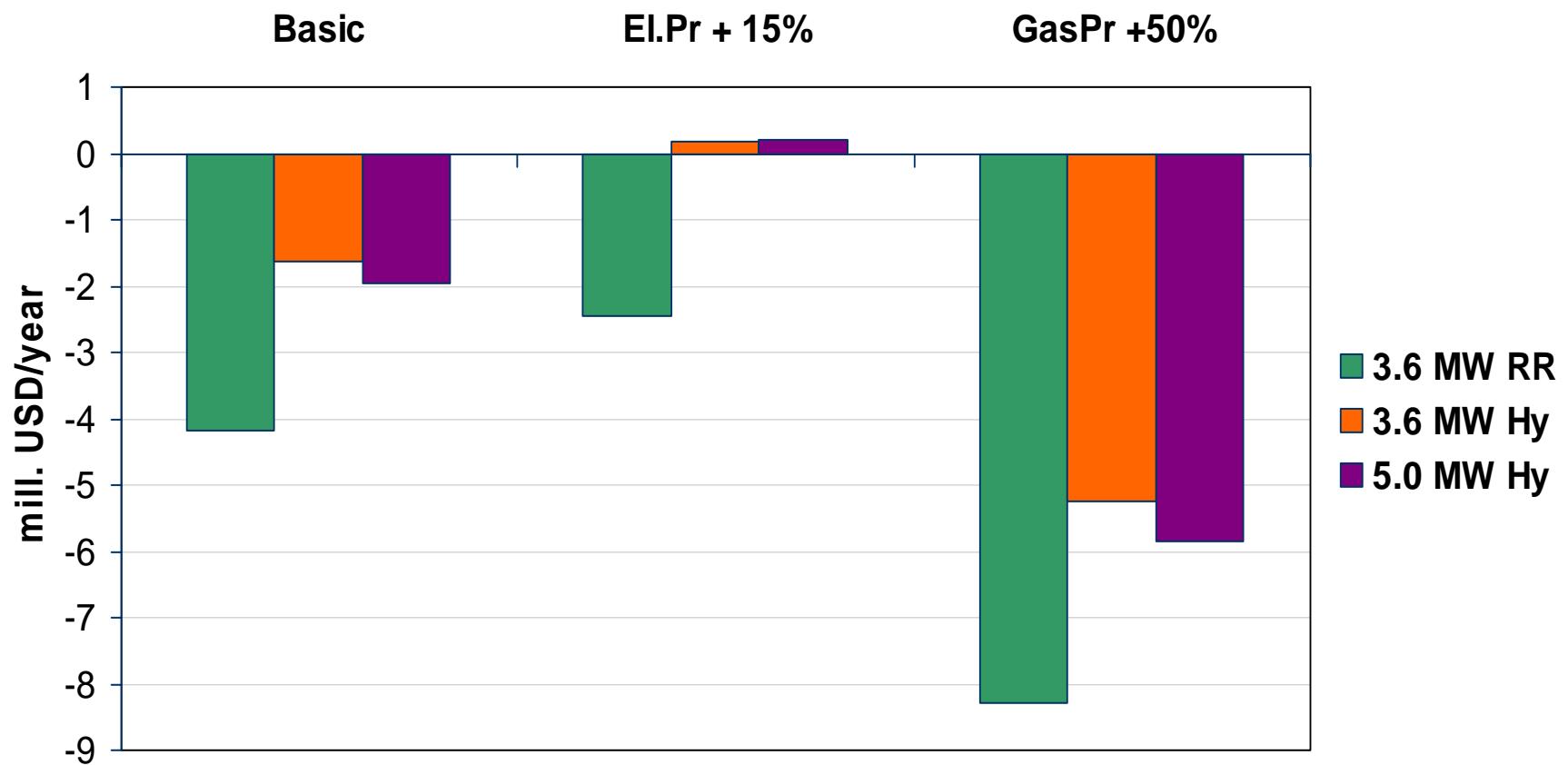
Annual operating costs

Gas price +50%

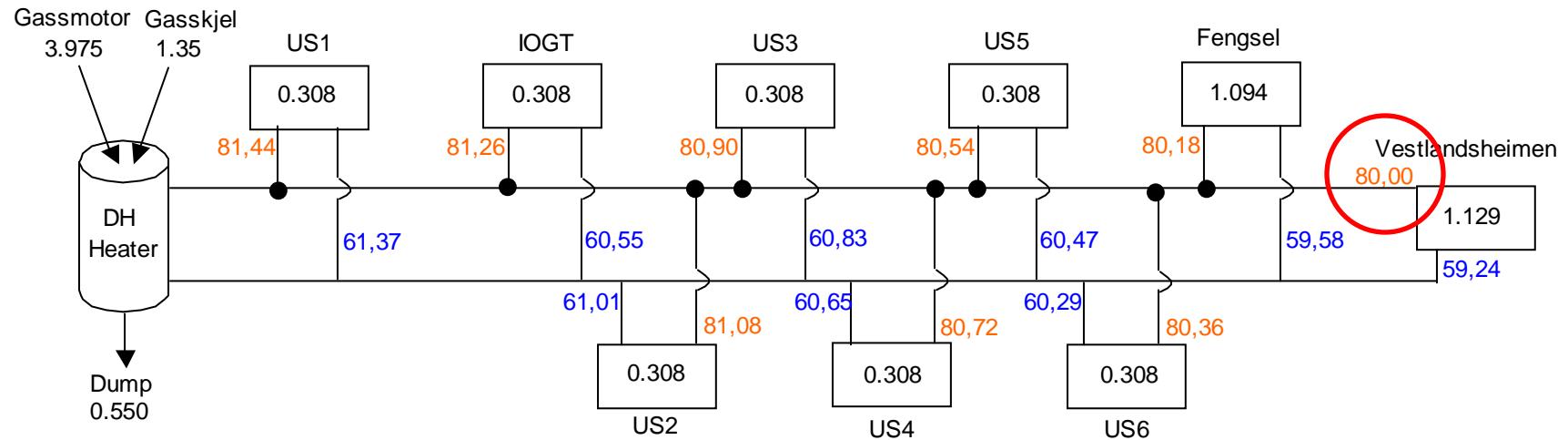


Net Present Values

Mill. NOK



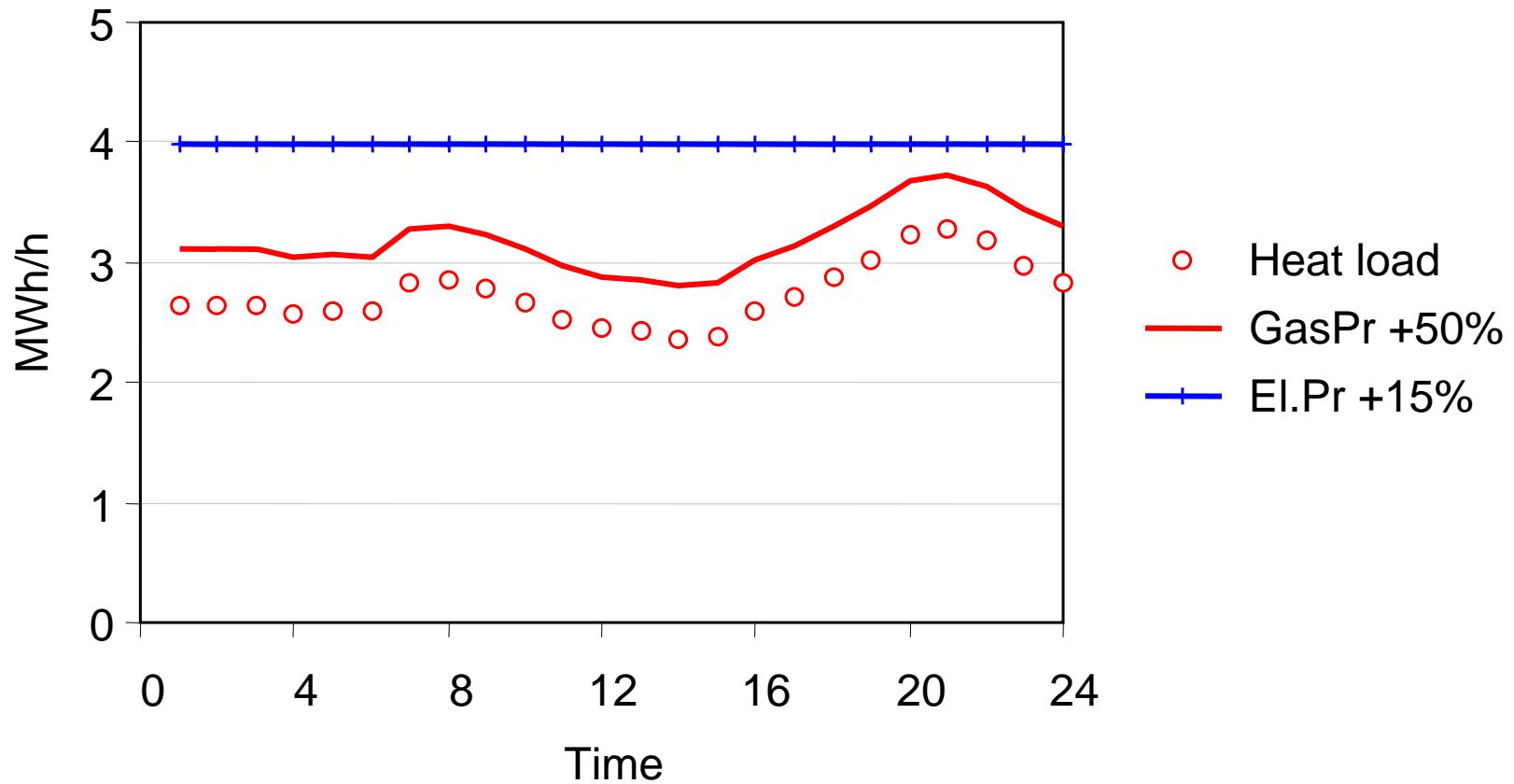
Critical temperatures and loads in DH grid



Criteria:

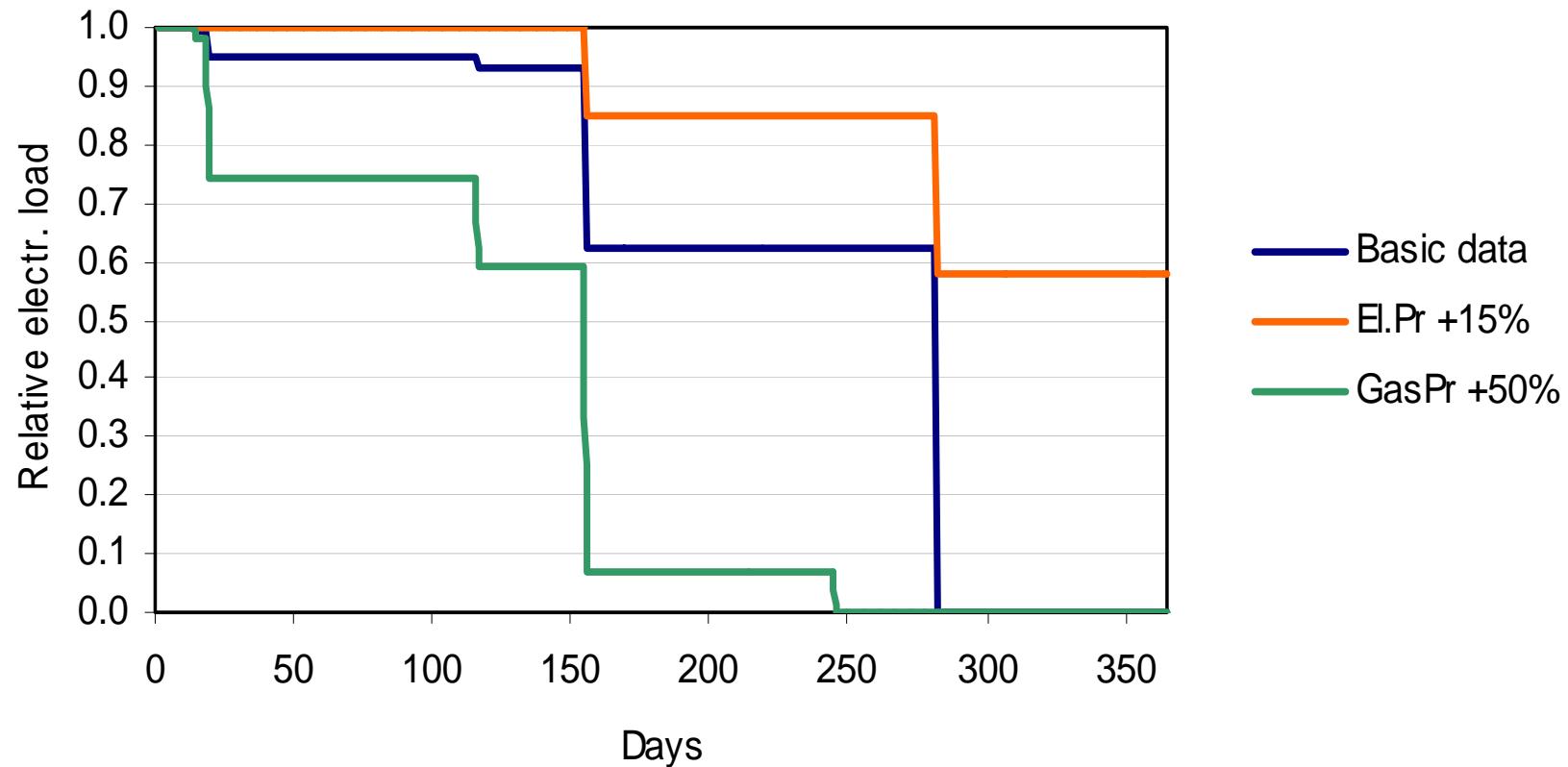
- $T_{out} > 80^\circ C$
- $T_{in} > 60^\circ C$
- $T_{cons} > 80^\circ C$

Samples of optimal heat generation

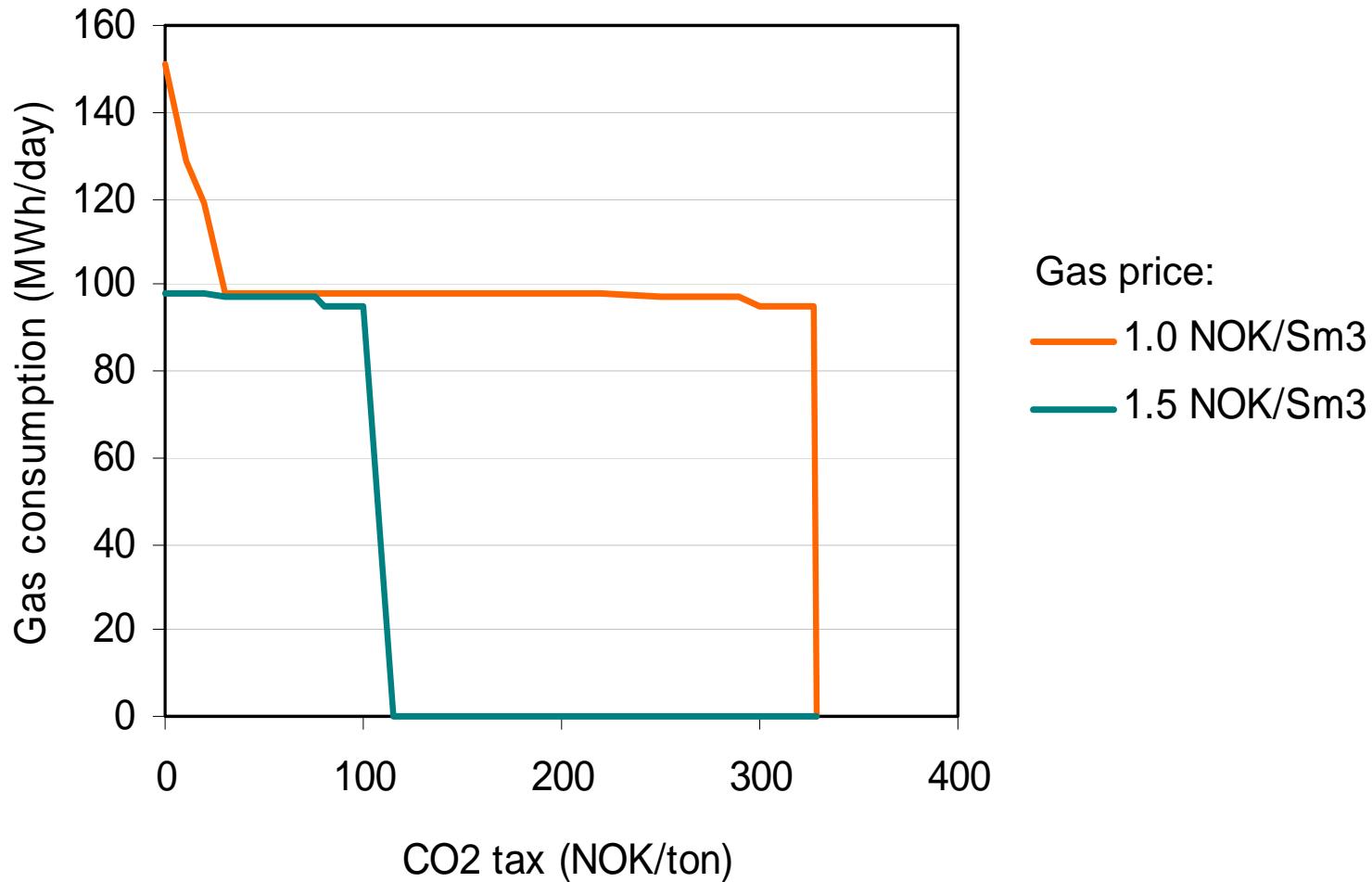


Duration curve

3.6 MW gas engine at Hylkje



Sensitivity to CO₂ tax



New Tool for Optimisation of Integrated Energy Service Systems

Applications

- Planning tool, not design tool!
- Planning of municipal energy systems
- Analyse mutual influence between different energy systems and infrastructures
- Evaluate construction of new DER power plants
 - size - location
 - technology - economy – environment
 - s.t. infrastructures for electricity, district heating and fuel(s)
- Evaluate up-stream infrastructure for DER fuels
 - road transport of biomass and waste
 - capacity of existing gas networks
- Evaluate "threats" from other DER and suppliers in the same area

Next steps...

- Prototype ready by 2005 (End of Stage 1)
- PhD student to implement MCDM methods
- Adding more technology modules (Hydrogen etc)
- Improving optimization algorithms
- GUI and DB implementation
- Stage 2: Further prototyping or commercialization?
- ...

Energy system analysis at SINTEF Energy Research

Overview of talk

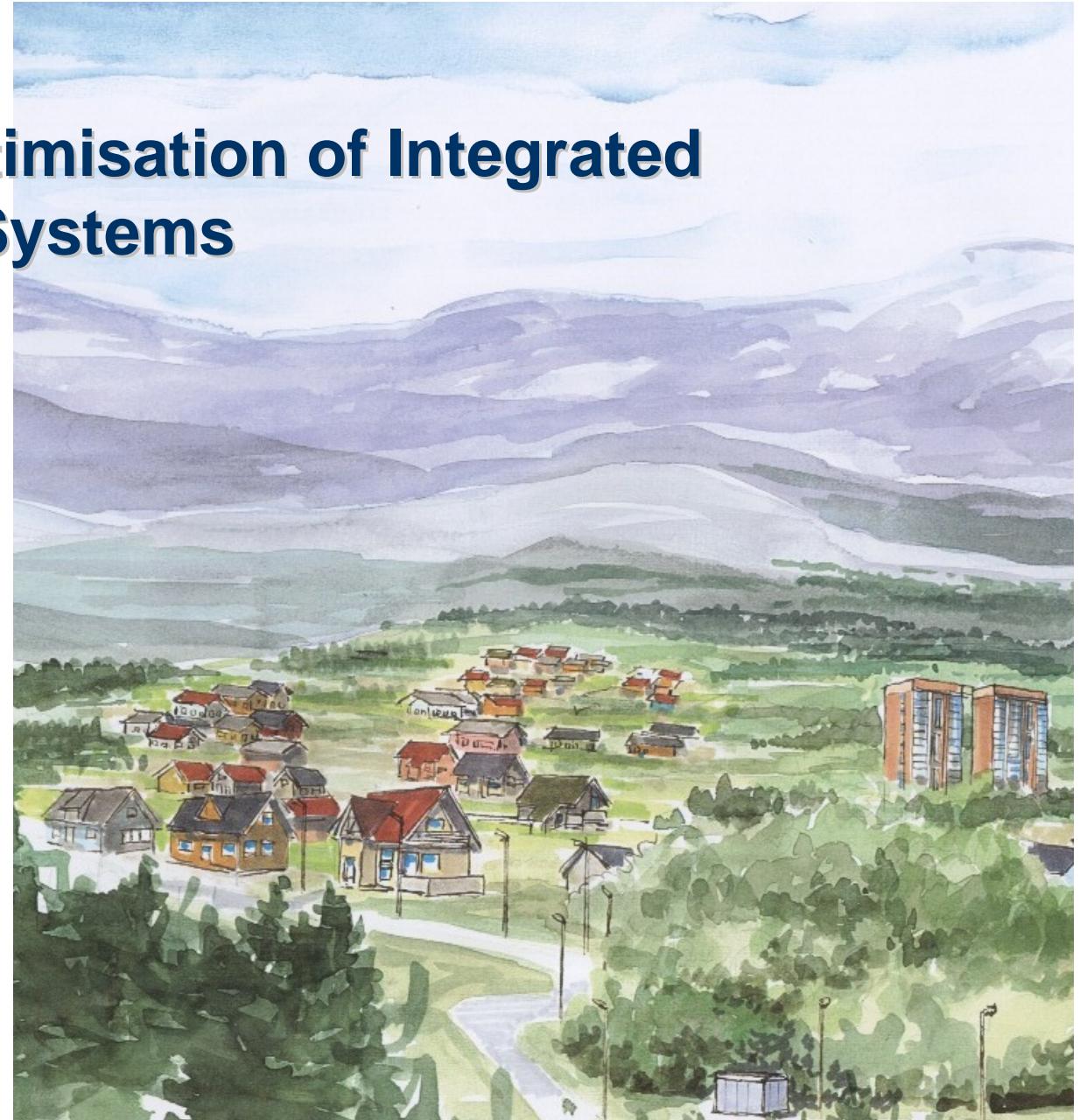
- Introduction to SINTEF
- Planning of Distribution Systems with Multiple Energy Carriers
- TRANSES - Alternatives for the Transition to Sustainable Energy Services in Northern Europe
- Multi-area Power Market Simulator EMPS
- Utilisation of transmission system capacity
- Integration of local energy sources by power electronic converters



New Tool for Optimisation of Integrated Energy Service Systems

Dr. Bjorn H. Bakken
bjorn.h.bakken@sintef.no

SINTEF Energy Research
N-7465 Trondheim
Norway
www.energy.sintef.no



New Tool for Optimisation of Integrated Energy Service Systems

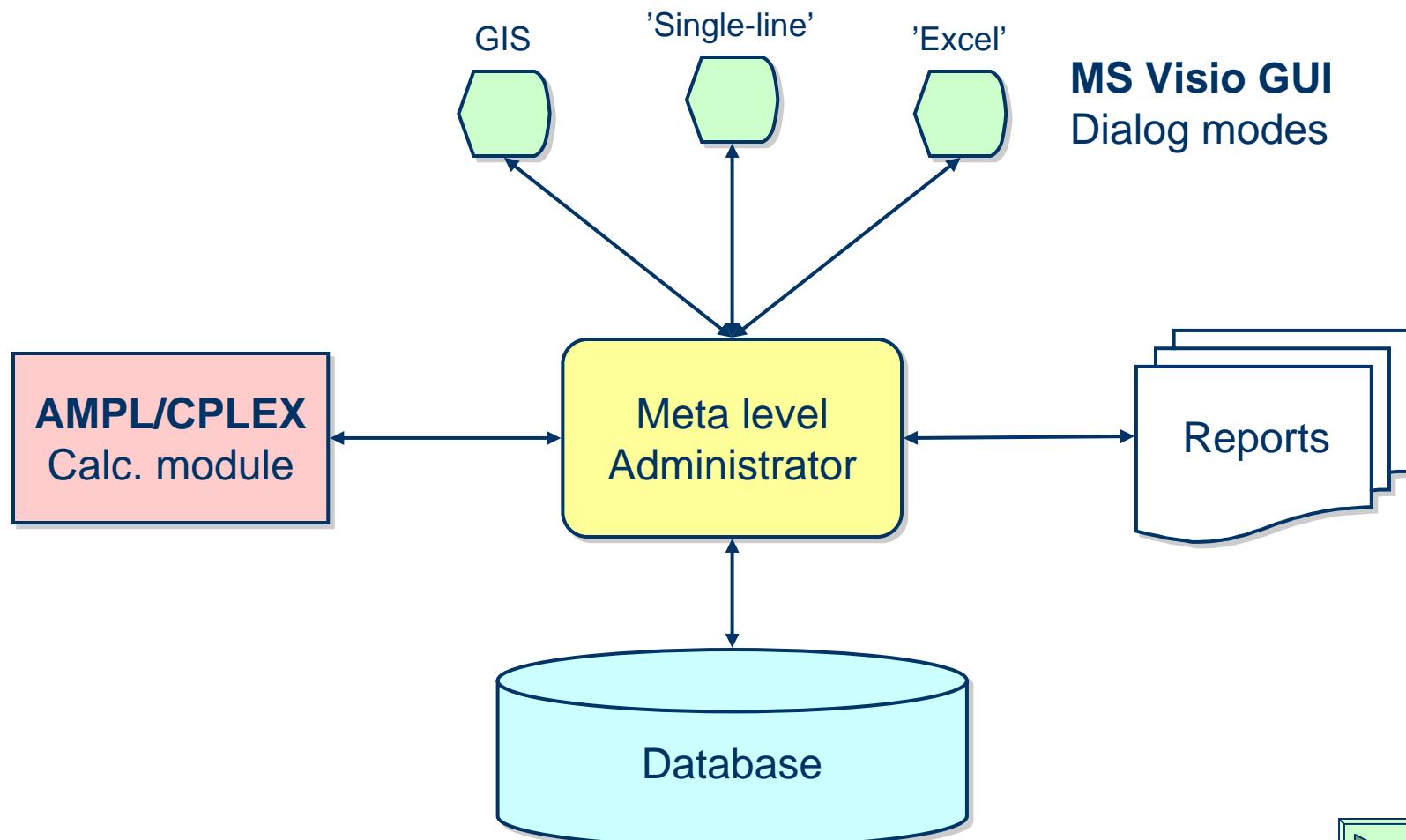
Sponsors

- Current budget: 300,000 USD/yr
- Norwegian Research Council (50%)
- Statkraft (Norw. State Power Company)
- Norsk Hydro
- Statoil
- Powel
- 4+ municipal energy service companies

Expansion planning

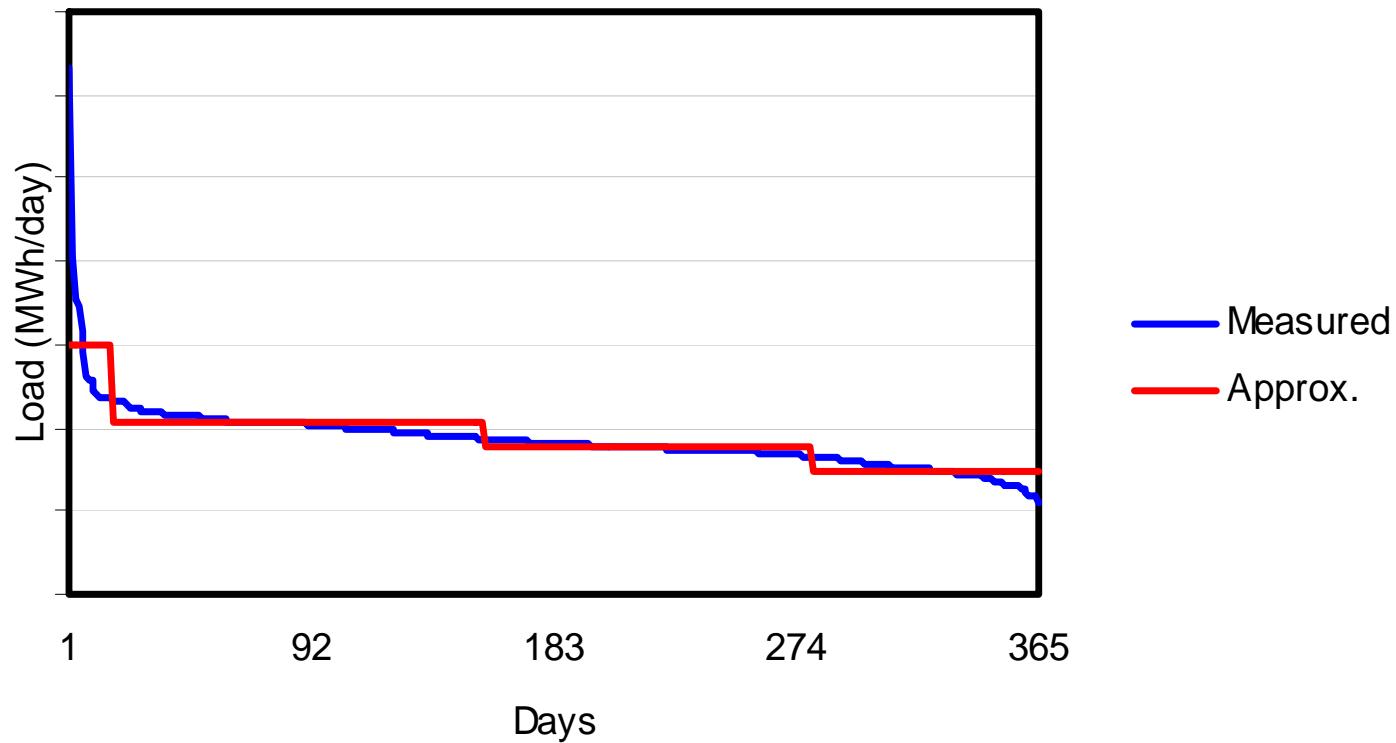
- Predefine set of relevant expansion Projects (States) to be evaluated
 - Each Project consists of one or more investment Objects
 - Each Object might be involved in one or more Projects
 - Minimize operating costs for each year for each State
 - Each year is split at least in 4 Periods
 - Establish matrix of operating costs: $C_{ts}^{ope} = \sum_{w \in \text{Periods}} \theta_w c_{tsw}^{ope} \quad \forall t, s$
 - Minimize $\left\{ \sum_{t \in T} \delta_t \cdot \left(t^{step} \cdot c_t^{ope} + c_t^{inv} \right) - \delta_{t^{end}} \cdot \Phi \right\}$
-

Program structure



Annual load segments, Bergen

	SEGMENT 1	SEGMENT 2	SEGMENT 3	SEGMENT 4
No. of days (θ)	18	137	126	84
Avg. temp. ($^{\circ}\text{C}$)	$T < -4$	$-4 < T < +6$	$+6 < T < +16$	$+16 < T$



Expected growth

AREA	NO. of DWELLINGS	PERIOD
Hylkje	90	2002-2005
Almås	650	2004-2011
Haukås	1200-1300	2008-2019

Spec. energy demand

